DETAILED IN SITU SAMPLING OF TWO DUST DEVILS IN MOROCCO

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Introduction

Here we report on in situ sampling of the dust load and the grain size distribution of different sample heights of two dust devils in the Sahara Desert in southern Morocco (Fig. 1; northwestern rim of the Erg Chegaga at 29°53'8"N, 6°19'6"W) during a field campaign in spring 2012 [1]. Former studies of in situ measurements of lifted particles in dust devils were published by [2-4], where only [3] presented vertical grain size distributions comparable to our work.

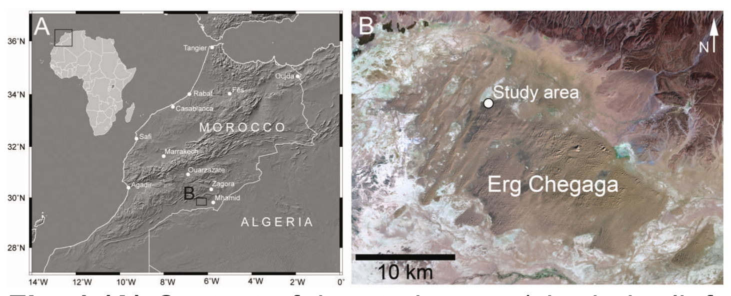

Fig. 1 (A) Context of the study area (shaded relief map from SRTM4 data [4]. **(B)** Erg Chegaga and location of the study area (Landsat 7 RGB image).

Dust devils are small vertical convective vortices which occur on Earth and Mars [e.g.,5,6]. On Earth they are most common during spring and summer in semi-arid to arid regions [7]. Dust devils consist of a low pressure region in the interior which is surrounded by tangential winds and updrafts [8,9]. These winds and updrafts lifted particles (dust and sand) which makes them visible [6,10]. Particles entrained into the atmosphere by dust devils have an influence on the (terrestrial) climate, weather, human health, and biogeochemistry [6,11,12]. Lifted small aerosols (Earth: ~<25 µm [6,11]; Mars: ~<20 µm [9]) can be entrained into the atmosphere as a suspension and probably transported across the whole globe. Larger particles (sand-size) remain at lower heights and build-up the so-called "sand skirt" of the dust devils [6,13], which reinforces the erosional significance of dust devils.

Data and Methods

For our in situ sampling we used a 4 m high aluminum pipe with sampling areas made of removable adhesive tape on one side, which was holding upright into the path of the dust devil [1]. After one passage of the dust devil, the sampling tape, which now had dust and sand grains adhered to it, was directly preserved on-site by sticking the sample patches onto glass slides. We took samples of two active dust devils: dust devil #1 with a diameter of ~15 m, and a sampling interval of 0.5 m between 0.1 and 4 m height; dust devil #2 was weaker (~4-5 m diameter) with a sampling interval of 0.25 m between heights of 0.5 and 2 m [1]. The maximum diameter of all particles at all sampling heights within a representative area of 0.5 cm^2 were measured using an optical microscope at a magnification of 200×. Estimations of percentage weights (wt%) of lifted particles were calculated under the assumption of being perfectly rounded, which is an overestimation and give the maximum volumes [1].

Fig. 2 Image of dust devil #1 during in situ sampling. Notice the author for scale.

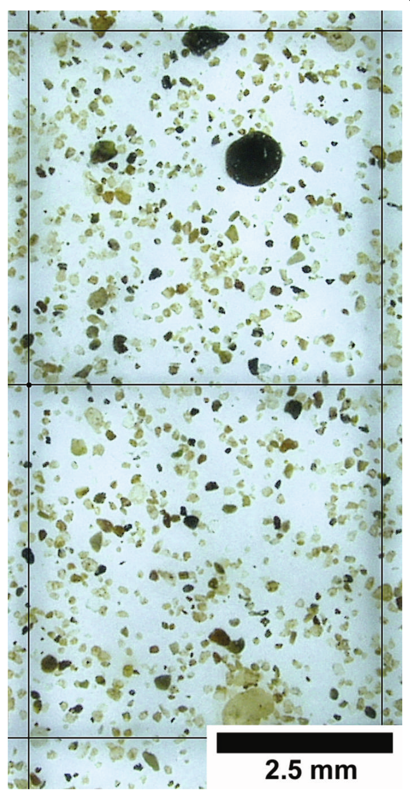

Fig. 3 Example of a measured in situ sample (here: dust devil #1 at 0.5 m height). The maximum diameter of all grains within the two quad-rangles (side lengths of 5 mm) were measured. Magnification is 20×.

Results Dust Devil #1 vs. Dust Devil #2

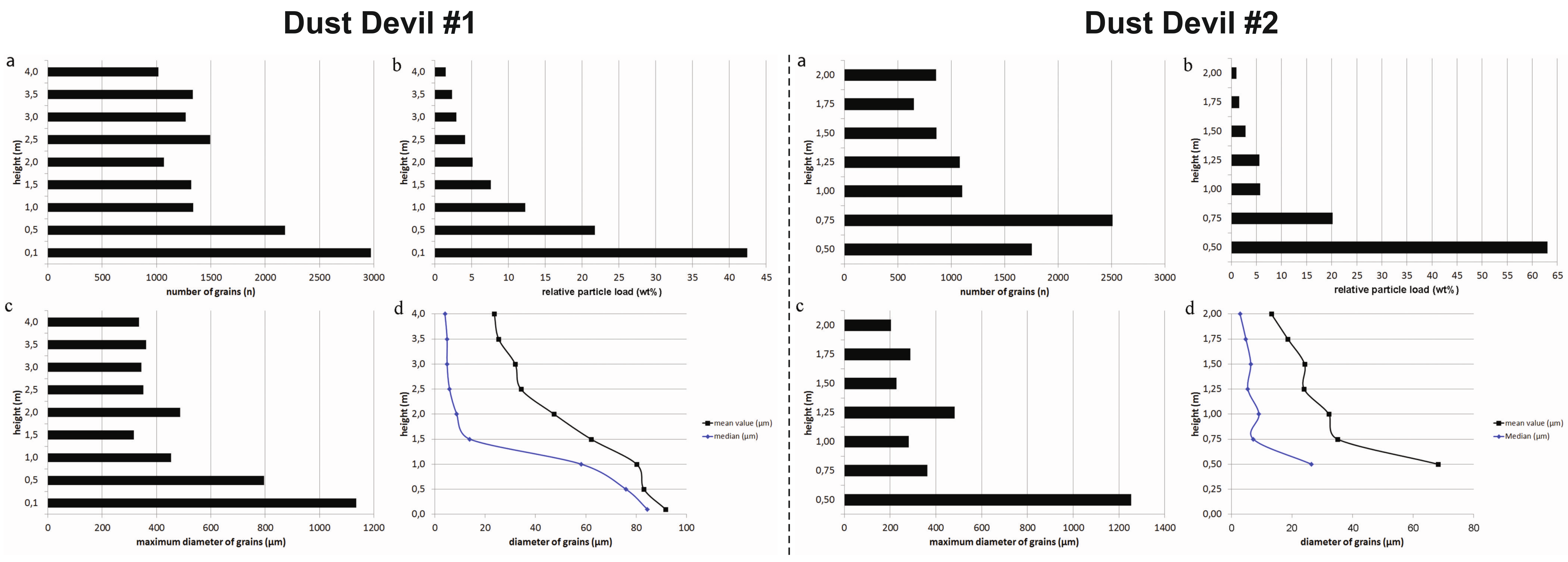

Fig. 4 Detailed investigations of both DD in all sample heights. All measurements were taken within 0.5 cm^2 of sample area (see also **Fig. 3**). **(a)** Number of measured grains vs. height. **(b)** Relative particle load (wt%) vs. height. **(c)** Maximum diameter of grains vs. height. **(d)** Mean value and median of the diameter of grains vs. height.

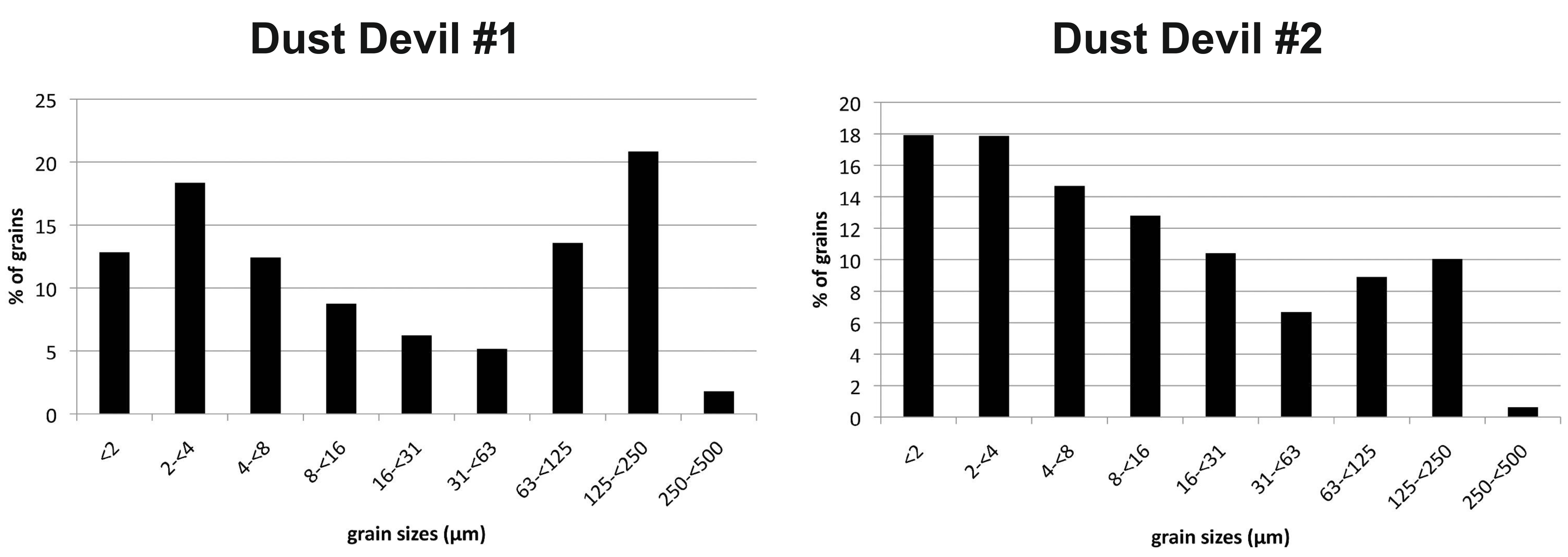

Fig. 5 Grain size distribution for both dust devils after the classification from [14] from clay to medium sand.

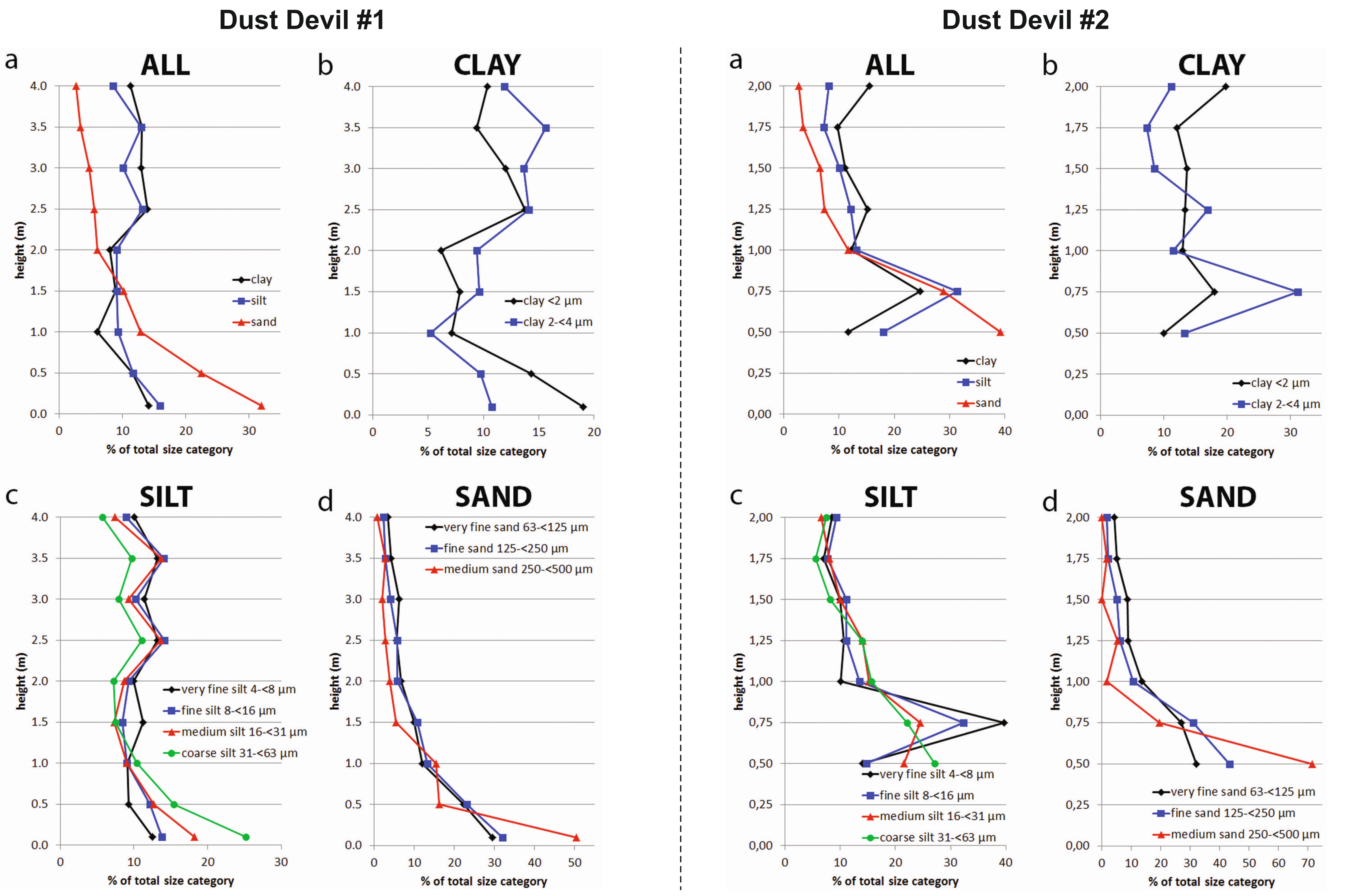

Fig. 6 Detailed grain size distributions for every sample height of both dust devils vortices. **(a)** Relative values of the total distribution of different particle sizes (clay, silt, and sand). **(b)** Relative values of the total distribution of clay. **(c)** Relative values of the total distribution of silt. **(d)** Relative values of the total distribution of sand.

Conclusions

Comparable internal structure of both dust devils, despite their different strengths and dimensions

- comparable trends of vertical grain size distribution and relative lifted particle load vs. height
- this is interesting in that both dust devils had different sizes and intensities, and also in that sample heights and sample intervals were different

Vertical trend of decreasing particle size with height

- leads to a nearly exponential decrease of particle load with height, which is in agreement with [3]

Impact on the atmosphere

- between ~60% and ~70% of the number of lifted particles could possibly go into suspension (~<31 µm, depending on the used grain size classification)
- due to the small diameters, this contributes only ~0.05 - ~0.15 wt% to the lifted particle load
- our measured values show much lower values compared to [4], who concluded that ~10 wt% can go into suspension
- on Mars, the amount of lifted particles will be general higher as the surficial dust coverage is larger [15,16], although the atmosphere can only suspend smaller grain sizes (~<20 µm) [9] compared to Earth

Direct evidence of sand skirts

- sand skirts contain the majority of lifted material, but large grain sizes will not be entrained into the atmosphere and fall back to the surface [6,13,17-19]
- ~76.5 wt% to ~89 wt% of the total lifted particle load were lifted within the first meter of the vortices
- between ~69% to ~82% of all lifted sand-grade grains were also transported only within the first meter
- in good agreement with [3,4]

Dust devils somewhat represent surface they move over

- fine sand (125 to 250 µm) contributes about 50 wt% to the total mass of lifted particles in both dust devils and is the second largest fraction (~33.7 wt%) of the surface (Fig. 7)
- largest fraction of the surface is very coarse sand (1000 to 2000 µm), which was not substantially lifted by both dust devils

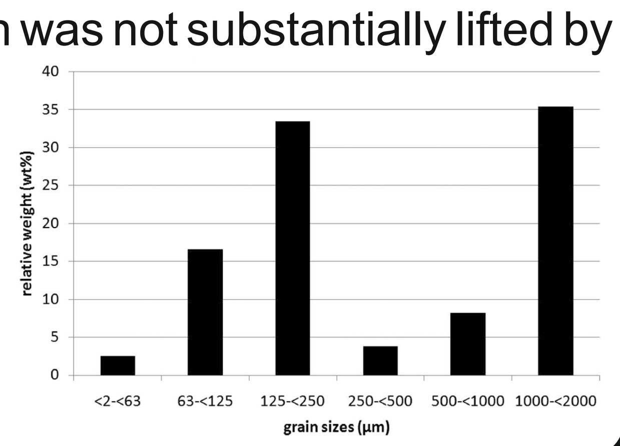

Fig. 7 Grain size distribution of the surface material within the study region (relative weight vs. grain sizes). Classification after [14].

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